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TITLE: THE CROSS-VALLEY STRUCTURE OF THE NOCTURNAL ALONG-VALLEY WIND IN BRUSH CREEK, COLORADO

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THE CROSS-VALLEY STRUCTURE OF THE NOCTURNAL ALONG-VALLEY WIND IN BRUSH CREEK, COLORADO

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1. INTRODUCTION

During September and October of 1984, the U. S. Department of Energy's Atmospheric Studies in Complex Terrain (ASCOT) Program conducted a series of meteorological experiments in the Brush Creek Valley of western Colorado (Gudiksen et al., 1984). The purpose of the study, which employed a variety of instruments, was to investigate the nocturnal katabatic wind in the valley and its morning breakup. One of the instruments, a doppler lidar operated by the National Oceanic and Atmospheric Administration's Wave Propagation Laboratory (NOAA/WPL), made detailed measurements of the along-valley component of the nocturnal katabatic wind in the valley (Post and Neff, 1986). We have used this data to examine the cross-valley structure of this wind.

2. BRUSH CREEK VALLEY

Brush Creek Valley is located approximately 50 kilometers north of Grand Junction, Colorado. It is one of a series of parallel valleys draining the Roan Plateau area south of the Piceance Basin. The valley is 25 km long and runs from northwest to southeast as shown in Fig. 1. The width of the valley floor ranges from 300 m at mid-valley to 700 m at its mouth. In the area of the valley where studies were conducted it is 600 m deep with 30° to 40° sidewalls cut by numerous small tributaries. The valley floor slopes gently (1.5°) down to the southeast.

3. DATA

The wind-sensing Doppler lidar was located, as shown in Fig. 1., at a point on the valley floor approximately 3.3 km up-valley from the mouth and at an elevation of 1821 m MSL. Scans were made both up- and down-valley in the sectors shown. Approximately each half-hour on experimental nights raster scans were made which resulted in the generation of 30 X 75 arrays of radial (along-the-beam) wind speeds at each of twenty ranges from the lidar. In the up-valley direction each array consisted of measurements at azimuths from 312.5° through 342.1° at a series of elevations from 0.5° through 12.1° above ground level. Both azimuth and elevation changed in 0.4° increments. Each wind speed is an average taken over 300 meters of the lidar beam centered at each of the range gates shown in Fig. 1.

Figure 2 is an example of the data density at the upvalley gate 18. This data provide cross-valley profiles of the along-valley wind component at various elevations above the valley floor. The

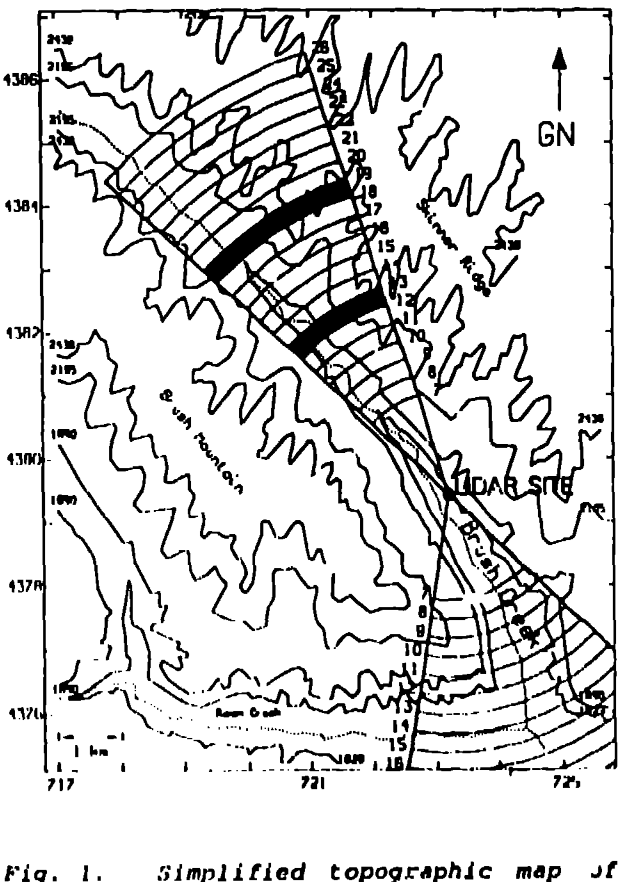

Fig. 1. Simplified topographic map of Brush Creek Valley. The location of the Doppler lidar, its scanning sectors, and range gates are shown. Range gates 12 and 18 used in this study are shaded. Contour lines are labeled in meters MSL and the top of the map is grid north.

valley cross section shown is the "control volume" for that gate developed and described by Horst (1986). "The most restrictive local cross-sections have been determined by calculating, as a function of along-valley distance, fall-line paths that originate on the valley bottom and climb to the ridge-line on each side of the valley. A control volume has been defined by projecting these fall-line paths onto a plane normal to the valley axis and averaging over an along-valley distance of 300 m, corresponding to the along-valley resolution of the Doppler lidar."

In the ensuing analysis we use the lidar data at two locations within the valley (upvalley gates 12 and 18) averaged from 0000 to 0600 MST on the mornings of September 20, 26, and 30 and October 6, 1984. The averaging period was selected to include the time when the katabatic wind was well established and in a relatively steady state. Only those cross-valley profiles that were within the katabatic flow were analyzed.

4. ANALYSIS

Figure 3 shows the nomenclature used. The valley cross-section at each gate is the control volume described above. The origin of the coordinate system shown is the lowest point in the control volume with z being positive upward and y being positive to the right when looking upvalley. Half-widths of the valley at elevation z are defined as shown for each side of the valley to account for asymmetry. The along-valley wind speed will be denoted by u.

Figure 4 shows the cross-valley wind speed profiles of u(z) as function of y for September 30 at gate 18 at 10 elevations from the ground to about 360 m. The flatter profiles occur at higher elevations above the ground. Similar profiles were found on the other three mornings at both locations in the valley. These profiles suggest that they are a family of parabolic curves. The data shown in Fig. 4 are used to illustrate the analysis procedure.

The profile data are normalized by the maximum wind speed and the valley half-widths to form the set

$$u(z)/u_m(z) \quad , \quad y/h(z) \qquad (1)$$

where $u_m(z)$ is the maximum wind speed of the profile at z and h(z) is the appropriate half-width as shown in Fig. 3. The normalized data of Fig. 4 are shown in Fig. 5 which substantiates that the profiles are to first order members of the same family of curves. The flatness of the ensemble is due to the fact that the maximum wind speed doesn't always occur at the same cross-valley location.

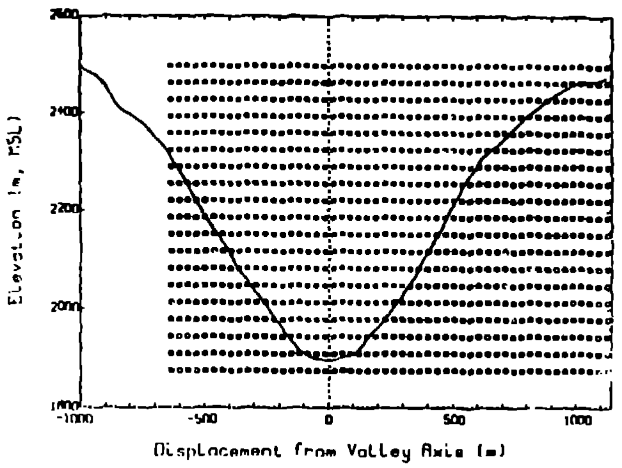

Fig. 2. Valley cross section and lidar data density at upvalley range gate 18. The solid circles denote positions where wind speed data were obtained.

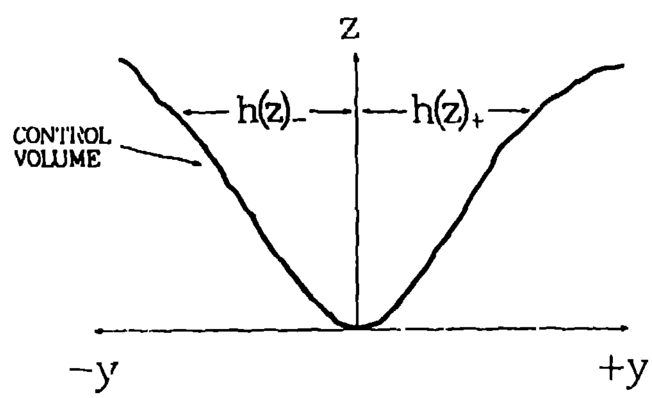

Fig. 3. Valley cross section looking upvalley showing nomenclature used.

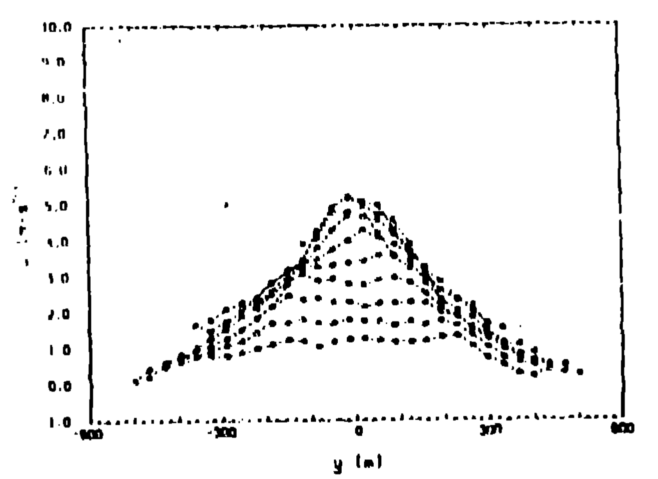

Fig. 4. Mean cross-valley wind speed profiles at gate 18 on September 30.

The normalized data for all profiles in Fig. 5 are then fit by the method of least squares to the parabolic equation

$$u(z)/u_m(z) = A + B[y/h(z)]^2 \qquad (2)$$

with no regard for which points belong to which profile. Fig. 6 shows the result of this fitting to the data of Fig. 5.

5. RESULTS

The analysis described above was applied to the two locations in the valley for the four nights with similar results. Table 1 gives the values of the fitting parameters A and B. The root-mean-square error in the fits for each case was very nearly 0.10.

The accuracy of the data and the goodness of the least squares fits suggest that a reasonable representation of the cross-valley structure of the along-valley wind in Brush Creek is

$$u(z) = u_m(z)(1.0 - 0.8[y/h(z)]^2) \qquad (3)$$

Furthermore, for valleys that are not too asymmetric h(z) can be taken as half the width of the valley at z.

6. IMPLICATIONS AND CONCLUSIONS

In the studies of valley meteorology detailed information on the winds throughout the valley are normally not available as in these experiments. In the more common situation vertical profiles of wind are obtained by either tethered balloon systems or doppler acoustic sounders in the center of the valley. Assuming horizontal homogeneity in the wind field has lead to over estimations of such quantities as the along-valley mass flux and mass flux divergence (Whiteman and Barr, 1984).

Using Eq. (2) one can show that in an arbitrary depth of the katabatic wind the along-valley mass flux F^* obtained by assuming horizontal homogeneity is related to the mass flux F obtained assuming a parabolic profile by

$$F = (A + B/3)F^* \qquad (4)$$

Using the numerical values of Eq. (3) gives

$$F = (0.7)F^* \qquad (5)$$

Which means that, at least in the case for Brush Creek, the assumption of horizontal homogeneity leads to an over estimate of the along-valley mass flux of 30 per cent and subsequently the same error in the mass flux divergence along the valley.

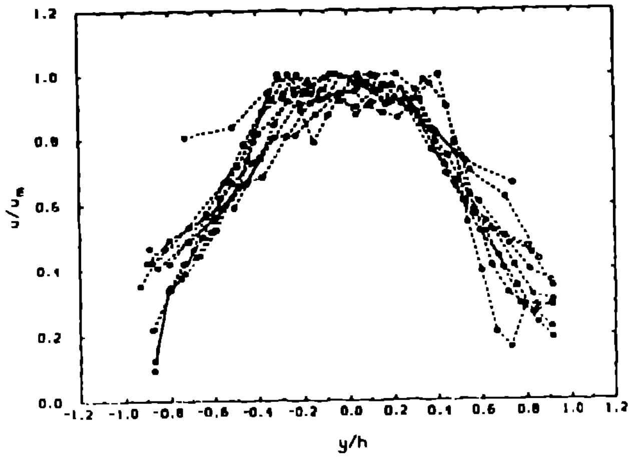

Fig. 5. Normalized profiles of Fig. 4.

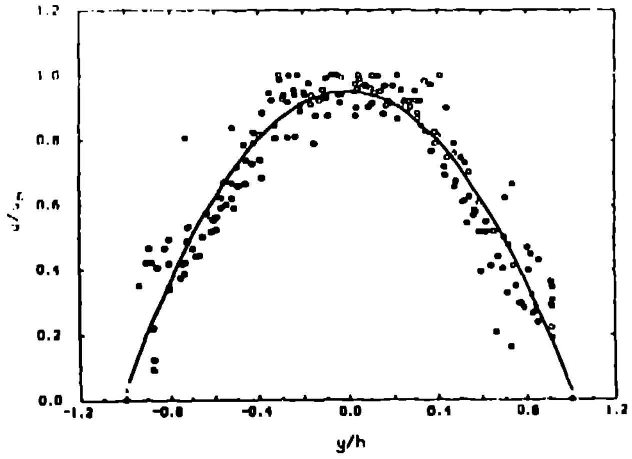

Fig. 6. Results of least squares fit of Eq. (2) to data of Fig. 5.

Table 1

Fitting Parameters for Equation (2).

	A		B	
Date	Gate 12	Gate 18	Gate 12	Gate 18
9/20	0.96	0.93	-0.85	-0.81
9/26	0.97	0.96	-0.84	-0.82
9/30	0.92	0.95	-0.86	-0.92
10/6	0.98	0.96	-0.75	-0.77
Mean	**0.95 ± 0.02**		**-0.83 ± 0.05**	

7. ACKNOWLEDGMENTS

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